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BUREAU OF MINES
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STENCHES FOR EMERGENCY WARNINGS IN METAL MINES

BY

D. HARRINGTON AND J. H. EAST, JR.

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STENCHES FOR EMERGENCY WARNINGS IN METAL MINES[1]

By D. Harrington[2] and J. H. East, Jr.[3]

Fires in metal mines have resulted in some of the worst disasters in American mining history insofar as loss of life is concerned. One fire caused the death of 163 miners and individual less spectacular fires have cost the lives of scores of workers. Metal mines are often very deep, and the men working on numerous levels far removed from direct communication with the surface. In many instances they cannot be warned quickly of an emergency or a mine fire by telephone or other usual method of communication, or by messenger, flashing lights, gongs, sirens, or whistles. Telephones are not paricularly effective as a means of warning unless placed at all strategic points and with attendants always on duty; though telephones well placed have a definite value in any well-planned emergency procedure in mines of all kinds. Messengers are slow and men working in remote parts of a mine would not receive a warning quickly enough. Most metal mines are not electrically lighted, except at or adjacent to shaft stations and in principal haulageways, and this limits the effectiveness of flashing lights. Electric gongs and sirens or whistles have been tried as warning signals, but the sound is quickly deadened and does not travel upward into the stopes, especially those of an extensive volume. Shutting off the compressed air is by no means satisfactory as a warning, as not infrequently it is stopped accidently, so that it loses its value as an alarm. The introduction of water into compressed air lines is undesirable as a fire warning and necessitates considerable care, especially in deep mines; pressure-reducing valves must be provided to reduce pressure that otherwise would break connections or split the pipe.

A quick, effective method of warning miners underground of the existence of an emergency requiring them to leave the mine immediately, such as a fire on the surface or underground, is provided by the introduction of stenches in the compressed-air lines. This method of warning is by no means experimental, inasmuch as it has been used successfully for many years in

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some mining districts. Experimental installations were made as early as 1918, the use of valeric acid as a warning stench in the Davis-Daly mine in Butte, Mont., having been reported in March 1918.

The Bureau of Mines experimented with various stenches as warning agents in 1918 and published two papers[4/] on the subject in 1920.

The velocity of air passing through compressed-air lines in a metal mine in active operation is very rapid, sometimes thousands of feet per minute, depending on the size of the pipe and the construction of the lines; hence, a stench is transmitted quickly to all parts of the mine in which the compressed air is employed, making it a desirable, very rapid, effective, and relatively inexpensive method of warning miners of an emergency.

NECESSARY PROPERTIES OF STENCHES

Katz, Allison, and Egy state[4/] that the chemical used as a stench warning should have the following properties:

Nontoxicity

Obviously a stench should not be toxic. In order to make the warning harmless under any possible conditions of mismanagement, nontoxicity or absence of injurious effects on the human system is the first necessity. Also, the vapor must have no lachrymatory or other irritating effect on the eyes, lest miners become unable to find their way.

Moderate Vapor Pressure

The vapor pressure of a chemical may be considered a measure of the rate of evaporation. The higher its vapor pressure, the more rapidly a substance evaporates and the greater the quantity of it that a given volume of air will hold. Moderate vapor pressure is needed to prevent the possibility of an excessive concentration of the chemical in any part of the air of a mine. Although it is advantageous to be able to create in the escaping air such concentrations as when diluted with the surrounding air in the mine will give the desired effect, yet the maximum concentrations possible should be low enough to prevent harmful effects, even if breathed undiluted for a time. By the use of chemicals with a lower vapor pressure, the breathing of vapors in excess of certain comparatively low concentrations is automatically impossible.

4/ Katz, S. H., Allison, V. C., and Egy, W. L., Use of Stenches as a Warning in Mines: Bureau of Mines Tech. Paper 244, 1920, 31 pp.
Fieldner, A. C., and Katz, S. H., Stench Warnings in Metal Mines: Bureau of Mines Rept. of Investigations 2153, 1920, 3 pp.

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Odor

The odor preferably should be disagreeable rather than pleasant in order to be most effective as a warning and should be distinctive so that there would be no danger of mistaking it.

Availability

Substances that can be readily obtained in the market at moderate prices are to be given preference, but if such substances do not answer the purpose, those that may be prepared without difficulty in the chemical laboratory are to be desired.

Stenches used as warnings should have a decided action, that is they should exert a positive effort because of their offensiveness; yet the stench must be of such a nature that no definitely harmful physiological effect will result if miners are trapped and cannot excape to the surface and must breathe air containing the odor.

Many chemicals have been tested in the laboratory by means of an apparatus known as the odormeter to classify the odor. Butyl mercaptan is probably best suited for use as a stench, but as it is difficult to obtain, another chemical, ethyl mercaptan, was selected as the most promising stench yet tested, though other chemicals manufactured locally have been used in some mining regions.

Ethyl mercaptan ($C_2 H_5 SH$) has the very disagreeable odor of rotting cabbage. The toxicity of the vapor was tested at the American University experiment station by the Chemical Warfare Service, United States Army, and found to be essentially harmless. The specific gravity is 0.838, boiling point is 98° F., and freezing point is -228° F. Less than 0.01 percent by volume of ethyl mercaptan vapor in air will give a strong odor.

METHOD OF USING STENCHES IN MINES

Various devices are used to introduce liquid stenches into the compressed-air line, the most common being one similar to a pressure sight-feed oil cup with pipe connections to the air line above and below the liquid. A needle valve usually controls the rate of feed of the stench liquid. The actual rate of feed is determined by using water instead of the stench liquid. The valve position is marked for the desired feed. The liquid preferably should drop onto a screen of 12 to 16 mesh placed at an angle inside the air line, which tends to prevent the drops of the chemical from being deposited on the bottom of the pipe; it also causes the liquid to volatilize readily. The screen should be cleaned after each use.

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The stench liquid should be introduced into the air line on the discharge side of the compressor and receiver so that it will enter the mine immediately. Valves should be provided to control the flow of the air through the device.

Ethyl mercaptan is usually purchased in hermetically sealed containers (either glass or metal), which fit directly into the injecting device; these containers are broken or punctured when wanted for use. It is difficult to prevent ethyl mercaptan containers from leaking after having been opened, so that it is customary to discard any remaining stench liquid.

QUANTITY OF STENCH LIQUID REQUIRED TO GIVE WARNING

The only sure way of determining how much stench liquid should be used to obtain the desired strength of odor in remote sections of the mine is by trial. Mines with strong ventilation currents, either natural or artificial, require the use of larger quantities of stench liquid, as the volume of air passing a given point is larger with corresponding dilution of the odor. Where men are scattered throughout workings with little or no ventilation, as is the case in many metal mines, it would be well to have "leaks" in the air line near the men farthest from the mine opening, as the stench will not diffuse rapidly in still air. These men could warn others on their way out to the shaft or mine opening. Usually the stench is released through compressed air used in drilling, pumping, or hoisting or for local ventilation of remote faces; but if no compressed air-operated mechanical equipment (drills, pumps, hoists) is employed the stench method will be ineffective unless leaks are present in the air lines.

It is stated in Technical Paper 244 that 8 cubic centimeters of stench liquid should be used for each 1,000 cubic feet of free air per minute entering the mine, and this should be introduced in 1 minute. The volume of air can be determined accurately enough by multiplying the volume of the air cylinders of the compressor by the number of revolutions made per minute by the flywheel. However, in most American mines the actual quantity of stench liquid necessary to give a positive warning is determined by experiment. Men with synchronized watches are stationed at predetermined places throughout the mine, and note the exact time when the stench is sufficiently strong to be readily noticeable. The exact time when the stench liquid is turned into the compressed-air line should not be known to the watchers. Recording the reported intensity of the odor and the time required for it to reach the most remote places will furnish the data needed to determine the quantity of stench liquid required.

Many American mines are equipped with stench warning devices, but data on actual use in emergency are not usually available. The annual report of the Chief Mine Inspector of Ontario includes a section relating to mine fires

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and the use of stenches to warn the men underground of fire is mentioned frequently. Some examples of the use of ethyl mercaptan in both American and Canadian mines are described briefly below:

1943 - American Iron Mine

Fire was discovered on January 27, 1943, in the shaft timbers after workmen had used an acetylene torch. The mine was ventilated by an electrically driven fan, and this shaft was used as the intake airway. The fire could not be extinguished quickly, and the stench (ethyl mercaptan) was turned into the compressed-air lines at 10 a.m. Additional warning was given by telephone and messengers. By 11:11 a.m. all but five of the 128 men underground were in safety. Rescue crews brought the five remaining men to the surface, and no lives were lost as a result of this fire.

1940 - Canadian Mine

Surface buildings about 100 feet from the shaft caught fire. The cage tender and shift boss were on the surface and 13 men were underground. The stench (ethyl mercaptan) was turned into the compressed-air lines, and the shift boss went underground to round up his men. Five men working in a drift got the stench warning. The other workmen, four on motors and four scalers, were not using air and did not receive the warning.

1937 - Canadian Mine

A fire occurred on the 14th level at a pump station. A general alarm was sounded, and stench was turned into the compressed-air line. The miners climbed out of the mine, and the last man reached the surface approximately 1 hour after introduction of the stench.

1937 - Canadian Mine

A fire was discovered on the 675-foot level, caused by the negligent use of an acetylene torch. It was extinguished in a short time, and the working shift was not brought out of the mine. Exaggerated rumors as to the extent and nature of the fire made it advisable to call the men from the mine. This was done by turning stench into the compressed-air line.

Early tests made in the deep gold mines of California and in some of the mines in Butte, Mont., that have very extensive workings revealed that not more than 20 minutes was required to warn the men farthest from the shaft, as against an estimated 1 to 3 hours required to warn them by messenger.

Considerable time has been spent in attempting to find an effective way to employ stenches in the ventilating-air current of metal mines using fans to augment and control ventilation. Experimental work is being done,

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but so far the ventilating-air current in either metal or coal mines has not proven satisfactory as a carrier of stench warnings, principally because of the low velocity of the air in remote sections of the mine and the large volume of air, with correspondingly large quantity of stench material, involved.

Stenches used as a warning of an emergency should be well-known to all employees, particularly those working underground and those whose work takes them underground occasionally. Probably the best method of familiarizing them with the warning is to have practice drills in which the procedure the men are to follow in a real emergency is carefully followed. As part of a drill, the foreman and shift bosses should be required to account for all men under their supervision, and the time required for all employees to reach designated places should be checked carefully. Practice drills should include stationing watchers at strategic points in the mine to determine the time required for the stench to reach every part of it, particularly those that are remote and not easily accessible. Some mines have used a trial room to familiarize their employees with the odor of ethyl mercaptan; the vapor is passed through a small nozzle or outlet and the employees smell it. Employees should not go into a room saturated with the odor, because it is very difficult to remove the odor from clothing.

The small cost of installing a device to introduce stenches into a compressed-air line as well as the small cost of the chemical used as a stench liquid make this a very desirable method of warning men underground of an emergency. Every mine using comressed air underground should install such a device and keep it ready for prompt operation; it is cheap insurance and a real safety measure that may save many lives if that "unexpected fire" should occur. Five different methods of injecting stench liquids into compressed-air lines are shown in the accompanying sketches, figures 1 to 7.

GENERAL INFORMATION

1. Injection of stenches into compressed-air lines is the quickest and probably most effective way of warning men underground of an emergency such as a mine fire.

2. Ethyl mercaptan is one of the best liquid stenches that can be used as a warning agent. It has a distinctive odor, is easily obtainable and relatively cheap, and is nontoxic even in heavy concentrations.

3. Satisfactory devices for injecting stench liquids into compressed-air lines can be made in almost any mine shop. The cost need not exceed $25, and often the device can be made of materials in stock.

4. Recent mine fires have demonstrated the necessity for requiring that all employees, particularly those underground, be familiar with the odor of the warning stench.

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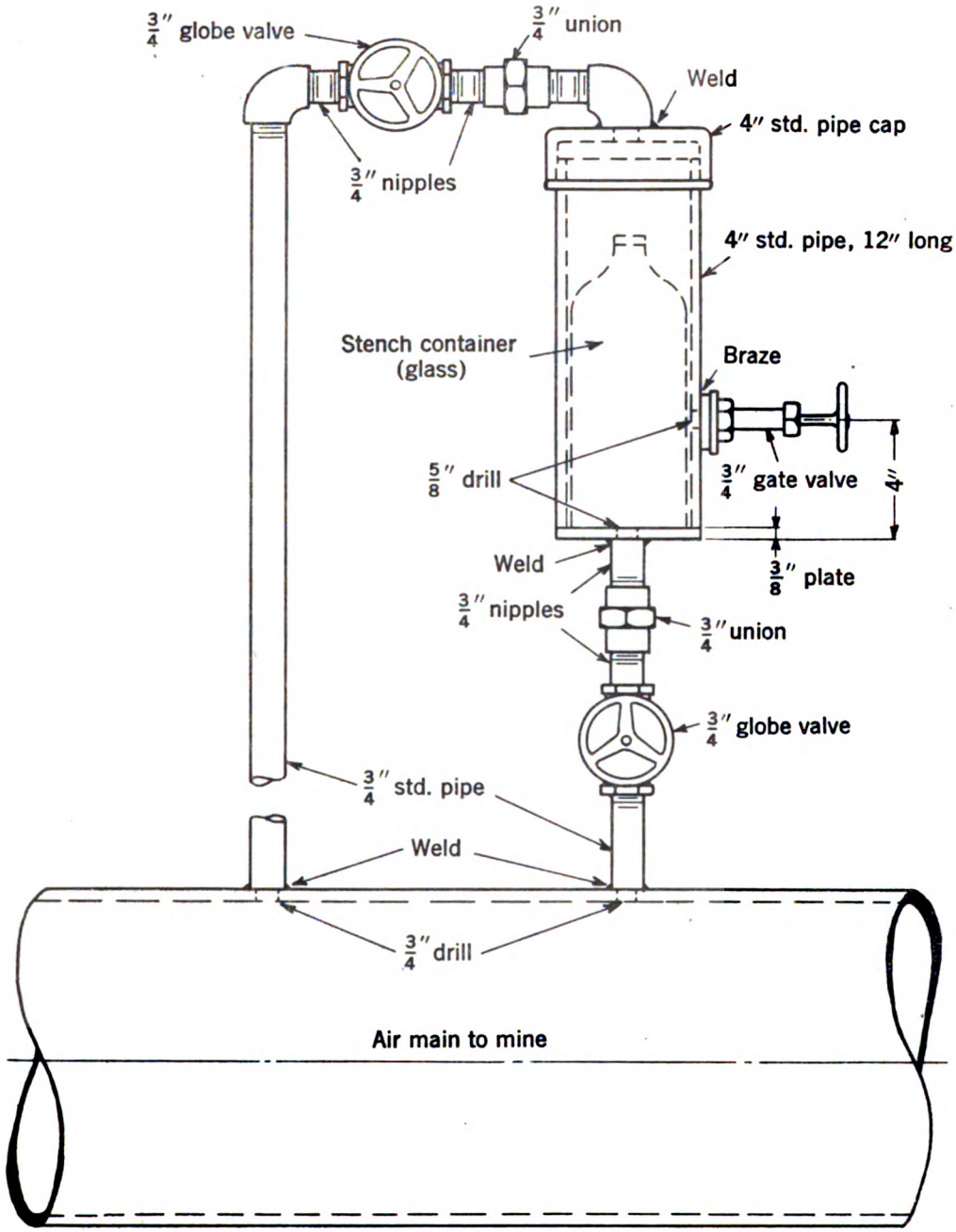

Figure 1.- Stench injector, mine no. 1.

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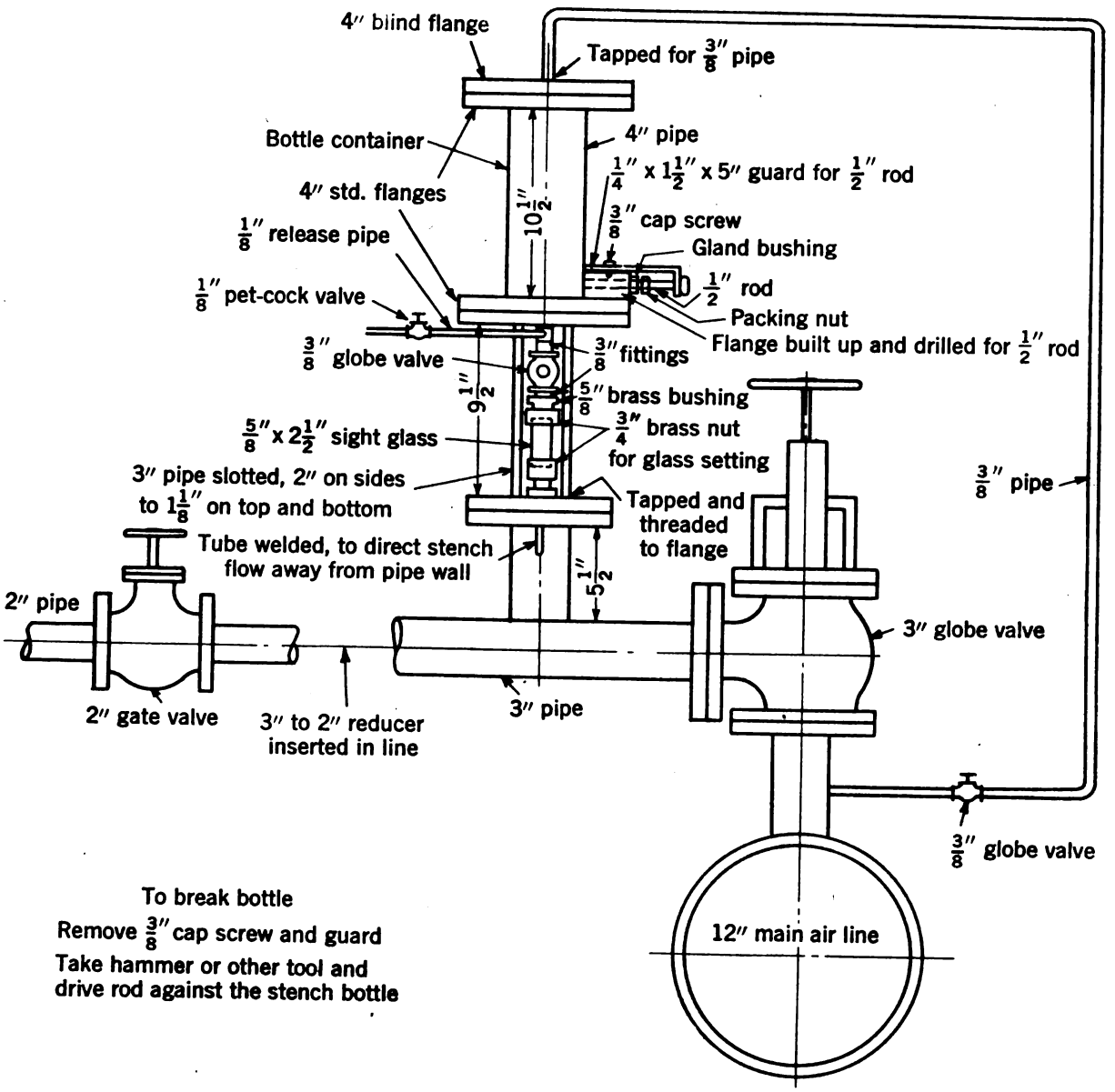
4″ blind flange
Tapped for 3/8″ pipe
Bottle container
4″ pipe
1/4″ x 1 1/2″ x 5″ guard for 1/2″ rod
4″ std. flanges
10 1/2″
3/8″ cap screw
1/8″ release pipe
Gland bushing
1/8″ pet-cock valve
1/2″ rod
Packing nut
Flange built up and drilled for 1/2″ rod
3/8″ globe valve
3/8″ fittings
9 1/2″
5/8″ brass bushing
5/8″ x 2 1/2″ sight glass
3/4″ brass nut for glass setting
3/8″ pipe
3″ pipe slotted, 2″ on sides to 1 1/8″ on top and bottom
Tapped and threaded to flange
Tube welded, to direct stench flow away from pipe wall
5 1/2″
2″ pipe
3″ globe valve
2″ gate valve
3″ to 2″ reducer inserted in line
3″ pipe
3/8″ globe valve
To break bottle
Remove 3/8″ cap screw and guard
Take hammer or other tool and drive rod against the stench bottle
12″ main air line

Figure 2.- General assembly of stench injector, mine no. 2.

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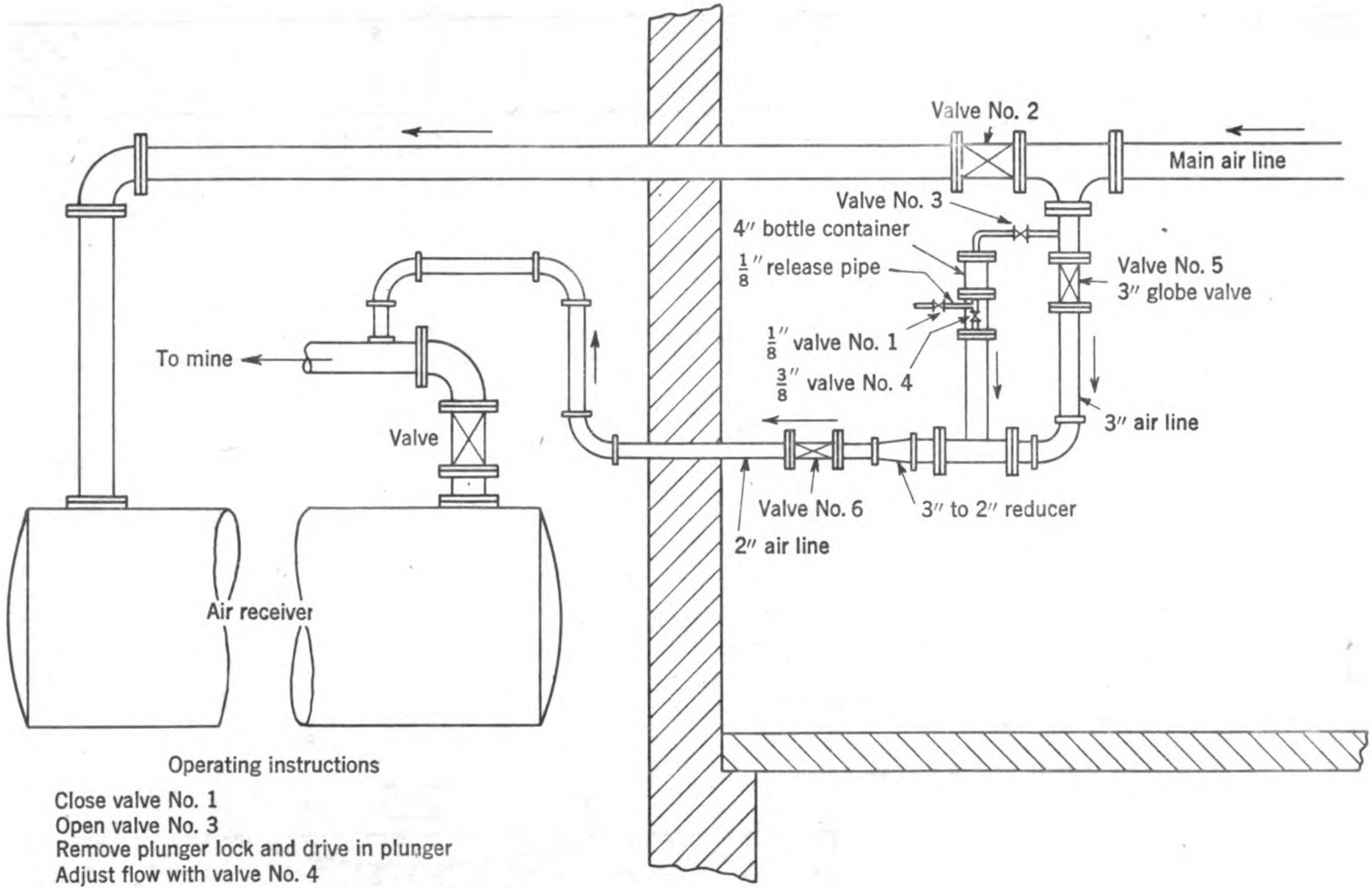
Valve No. 2
Main air line
Valve No. 3
4″ bottle container
1/8″ release pipe
Valve No. 5
3″ globe valve
1/8″ valve No. 1
3/8″ valve No. 4
To mine
Valve
3″ air line
Valve No. 6
3″ to 2″ reducer
2″ air line
Air receiver
Operating instructions
Close valve No. 1
Open valve No. 3
Remove plunger lock and drive in plunger
Adjust flow with valve No. 4
Valves No. 5 and No. 6 shall be open at all times
Main air-line valve No. 2, if installed, to be open at all times

Figure 3.- Stench injector assembly, mine no. 2.

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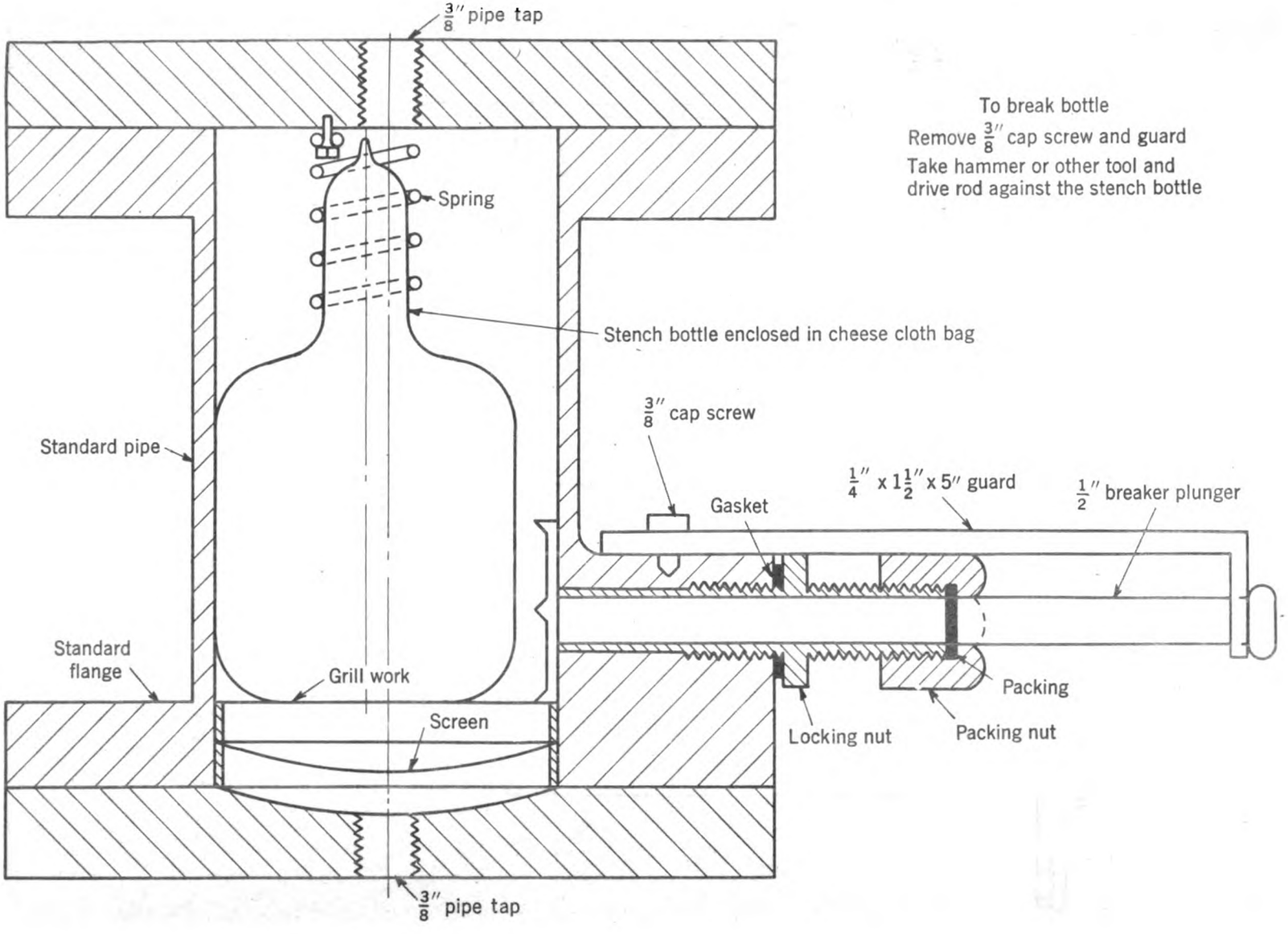

Figure 4.- Stench-bottle container and breaker, mine no. 2.

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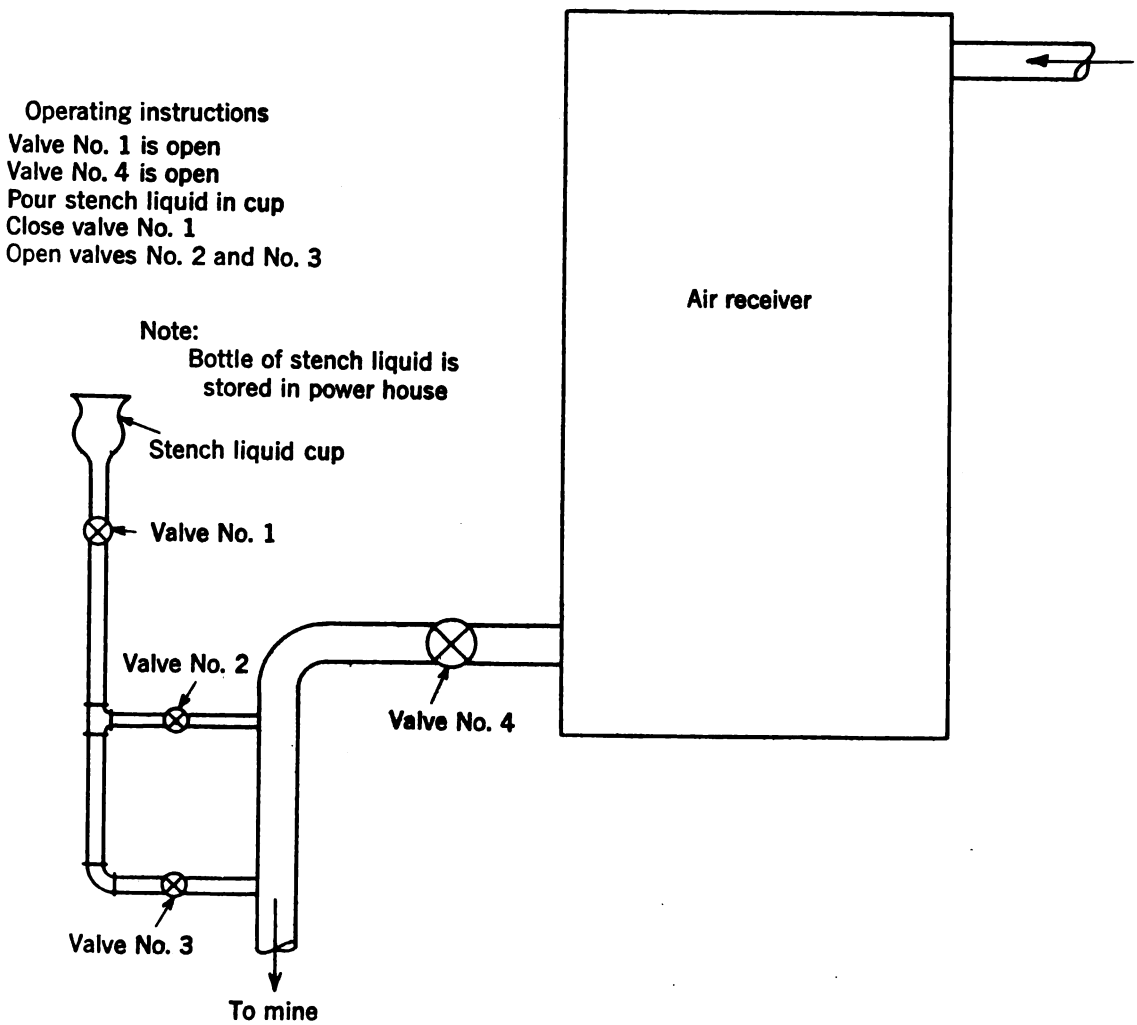

Figure 5.- Stench-injector device, mine no. 3.

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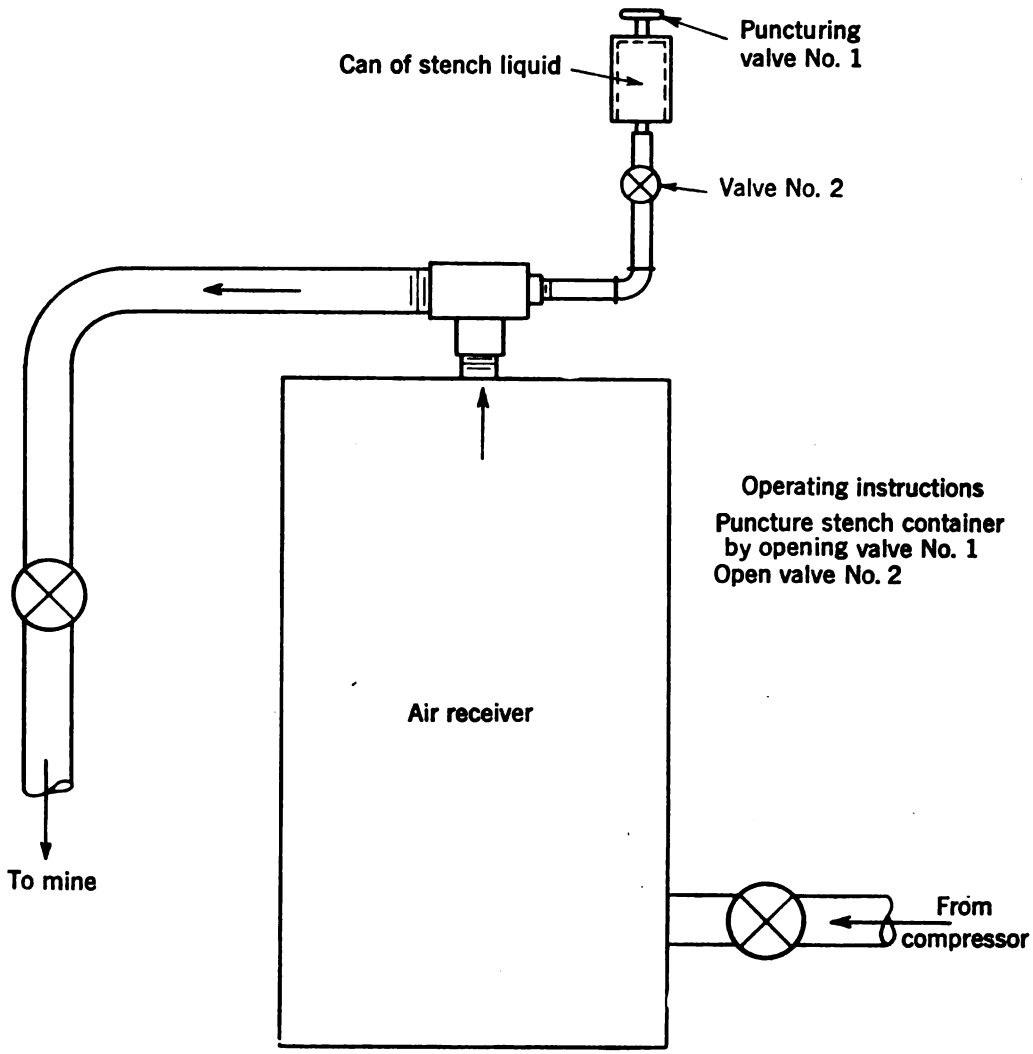

Figure 6.- Stench-injector device, mine no. 4.

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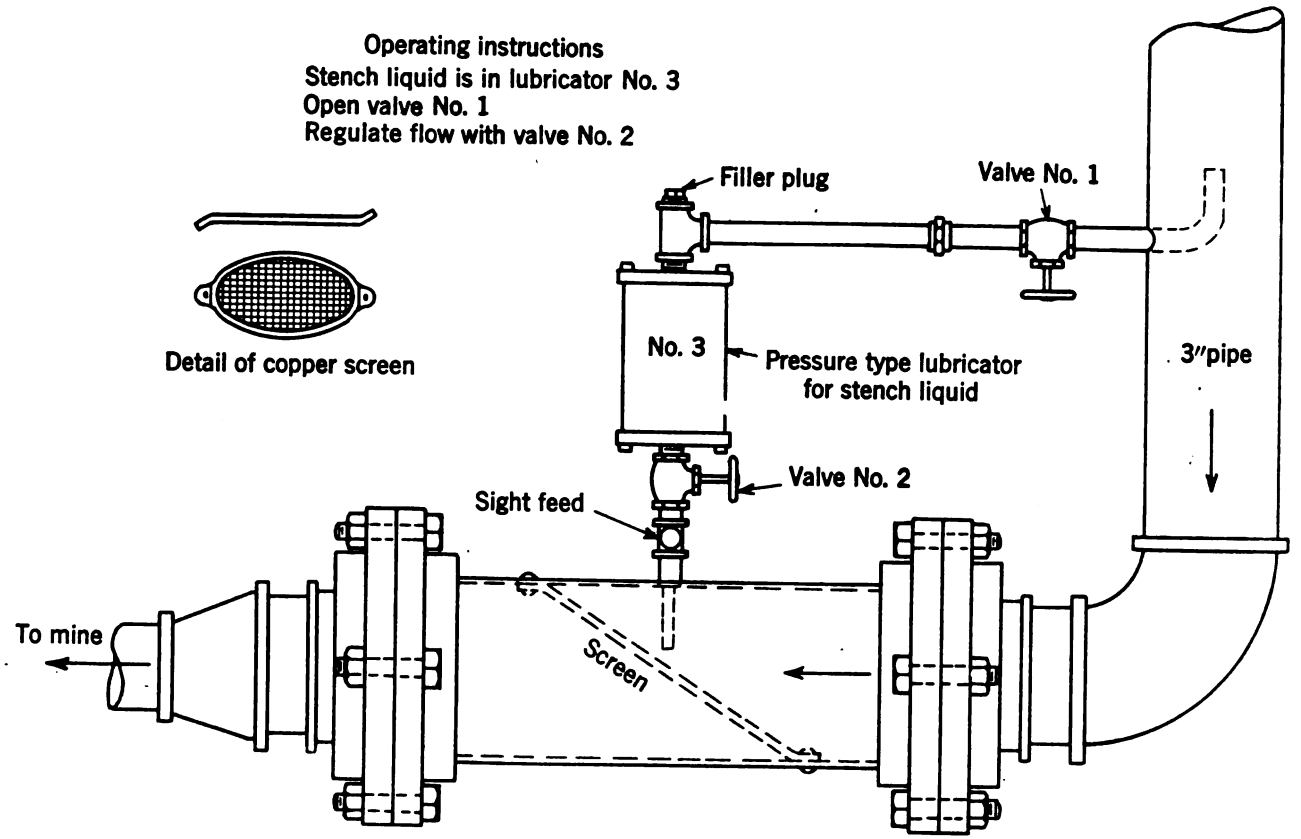

Figure 7.- Stench-injector device, mine no. 5.

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5. A well-planned procedure should be adopted for underground employees to follow when the stench warning is given.

6. Practice drills should be given once or twice a year and should include having all underground employees gather at designated places. The time required for the stench to reach the more remote sections of the mine should be noted, as well as the time required to assemble all employees at the designated places ready to leave the mine. Foremen and shift bosses should be responsible for having every man under their supervision respond to the alarm.

7. The stench used as a warning agent should be blown out of the working places as quickly as possible after each practice use, otherwise a real alarm might not be noticed by the employees, moreover, although the odor is essentially harmless, it is definitely disagreeable to some persons.

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